Associative Priming in Perceptual Identification: Effects of Prime-Processing Requirements

Jennifer S. Burt

University of Queensland, Brisbane, Queensland, Australia

Michael B. Walker

University of Illinois, Champaign, Illinois

Michael S. Humphreys

University of Queensland, Brisbane, Queensland, Australia

Gerald Tehan

Darling Downs Institute of Advanced Education, Toowoomba, Queensland, Australia

Running head: ASSOCIATIVE PRIMING IN PERCEPTUAL IDENTIFICATION

Abstract

Two experiments assessed the effects of prime-processing instructions on associative priming in word identification. In Experiment 1, groups instructed to read the prime silently or generate silently an associate of the prime showed a larger accuracy benefit for related over unrelated targets than a group that decided whether an asterisk was right or left of the prime. Additionally, the two groups showed a larger repetition benefit in an identification test for primes than did the asterisk-search group. On a cued-recall test for primes Group Generate was superior to the other groups. Experiment 2 used a group who provided estimates of target predictability by guessing for each prime the identity of the to-be-presented target. Generate and Read groups showed a greater priming effect than expected for a simple predict-and-match strategy. The results suggest that associative priming in word identification varies with the degree of perceptual but not elaborative processing of the prime.

Associative Priming in Perceptual Identification: Effects of Prime-Processing Requirements

Associative priming, the facilitation of lexical decisions to a target word (e.g., BUTTER) when it is preceded within some seconds by an associated "prime" word (e.g., BREAD) is well documented (Becker, 1979; Fischler & Goodman, 1978; Lorch, 1982; Meyer & Schvaneveldt, 1971; Meyer, Schvaneveldt & Ruddy, 1974). An explanation of priming which found early acceptance is that target recognition is facilitated by pre-excitation of the target word node in lexical memory as a consequence of the greater "spread of activation" from the prime node to nodes for associated words than to nodes for unrelated words. This selective activation arises because nodes for associates of a word are closer or more accessible to it than are nodes for unrelated words (Collins & Loftus, 1975).

The spread of activation account, and other accounts postulating the priming effect to be an automatic process consequent on prime recognition, have received empirical support. For example, Fischler (1977) reported that lexical decisions to a pair of associated words were faster regardless of subjects' expectancies about the relatedness of pair members. However, it has become clear that the priming phenomenon is subject to the influence of conscious expectancies or attentional strategies. Neely (1977) employed a small number of repeatedly presented primes paired with predictable, normatively related or unrelated targets. On the basis of comparisons with neutral prime (XXXX) trials, he identified a fast, automatic, inhibitionless priming effect occurring at short (250 ms) prime - target stimulus onset

asynchrony (SOA), and an attentional effect with an inhibitory component, occurring at longer SOAs (2000 ms).

Neely viewed the attentional priming process in his study as a "predict and match strategy" which produces a savings in recognition time when subjects correctly predict the target. On unrelated trials subjects pay a cost for incorrect predictions because the mismatch between target and predicted word biases them towards an incorrect "no" (non-word) response. Evidence for a similar kind of expectation strategy was reported by Becker (1980), Burke, White and Diaz (1987), and Den Heyer, Briand and Smith (1985). Other findings consistent with a prediction strategy are that greater priming effects occur when the proportion of related prime-target pairs is high compared to when it is low (Tweedy, Lapinski & Schvaneveldt, 1977; Tweedy & Lapinski, 1981). At long but not short prime-target SOAs, Den Heyer (1985), Den Heyer, Briand and Dannenbring (1983) and de Groot (1984) have observed an increase in both facilitation and inhibition as the proportion of related pairs increases.

The generality of Neely's findings is questioned by recent evidence that subjects do not use a prediction strategy in a pronunciation task (Lorch, Balota & Stamm, 1986; Seidenberg, Waters, Sanders & Langer, 1984; Stanovich & West, 1983; West & Stanovich, 1982). A more serious problem, which challenges the status of the lexical decision task as a tool for investigating lexical access, is the argument made in the latter three papers that apparent attentional effects in lexical decision arise from a strategy occurring after lexical access of the target. This strategy, termed "meaning integration" by Stanovich et al.,

consisted of subjects' checking the prime and target for relatedness, with a consequent bias towards a "yes" decision for related pairs and a "no" decision for unrelated pairs. Evidence for this kind of strategy in lexical decision has been reported by de Groot (1984, 1985) and den Heyer (1985) (see also Chumbley & Balota, 1984). Thus the pattern of facilitation and inhibition reported in previous studies may result from a meaning integration strategy which is an artifact of the lexical decision task.

Investigations of target predictability in associative priming are not the only source of evidence for attentional or strategic contributions to priming effects. A parallel line of enquiry, which is the focus of the present research, has been concerned with manipulation of instructions for responding to the prime. A number of "depth-of-prime-processing" experiments have found that associative priming is greater when a semantic rather than non-semantic approach is taken in prime processing. These results suggest the involvement of attentional deployment or other non-automatic processes. Parkin (1979) used Warren's (1972) version of the Stroop task, in which Warren found that naming the colour of a coloured target (e.g., QUEEN) was delayed, relative to an unrelated prime condition, when subjects were holding a related prime (e.g., KING) in memory. Parkin found that priming interference was observed when subjects made a semantic judgment (pleasant or unpleasant) about the prime but not when a phonemic judgment (1 or 2 syllables) was made. The Stroop results have been replicated by Henik, Friedrich and Kellogg (1983), with subjects naming the prime or performing a letter

search on the prime. The latter authors also extended their prime processing effects to a lexical decision task.

Smith, Theodor and Franklin (1983) compared five prime processing conditions in a lexical decision task: namely, visual analysis (say whether a star was present near the prime), letter search, number-of-syllables judgment, reading the prime silently and semantic analysis (say if the prime represented a living thing). The results showed the associative facilitation of target lexical decisions to increase as the depth of prime processing increased, with no facilitation for the first two conditions. Bentin and Katz (1984) argued however, that the physical orienting tasks used by Henik et al. and Smith et al. discouraged the subjects from attending to the prime "as a whole word". The non-semantic orienting task in their lexical decision study, an upper vs. lower case judgment about the prime, produced priming as strong as that observed when subjects made lexical decisions to both prime and target.

The notion of "whole word" prime processing, which Bentin and Katz advance to support their argument that priming is an automatic process, implies a clear-cut distinction between adequate and inadequate perceptual processing. However, recent evidence suggests a continuum of perceptual analysis. Of particular relevance to the present experiments is a study of repetition benefits in perceptual identification, a task requiring words to be named after brief masked visual presentations. Jacoby (1983) observed that repeated words are identified more readily than once-presented words, consistent with previous research in perceptual identification and lexical decision tasks (e.g., Evett & Humphreys, 1981; Jacoby & Dallas, 1981; 1982; Kirsner, Milech, &

Standen, 1983; Scarborough, Cortese & Scarborough, 1977; Forster & Davis, 1984). Significantly, Jacoby also observed a progressive increase in the repetition effect over three conditions varying the extent of "data-driven" processing engendered for the first presentation of a repeated word. Least facilitation was produced by subjects' generating the first presentation of a word (say the antonym of a cue term, e.g. COLD given HOT), an intermediate amount by reading the word in context (read COLD after seeing HOT), and most by reading the word in isolation. The most important implication of Jacoby's (1983) finding for the present studies is that it is possible to measure the amount of perceptual processing instead of arguing on the basis of intuition as Bentin and Katz (1984) did, whether a particular task involved "whole word" processing.

The present studies investigated depth-of-prime-processing effects in a perceptual identification task. This task is a useful vehicle for studying associative priming effects as it is unlikely to be affected by meaning integration strategies, because subjects are asked to identify words rather than make a classificatory response that is susceptible to bias. It does have a problem, however, with guessing strategies based on expectations about the kind of target which follows primes. This issue was addressed in the second experiment where a control group guessed the target that was to follow the prime.

The first experiment employed three prime processing tasks that were assumed to vary in the extent to which they fostered semantic and perceptual processing of prime words. In order to avoid carryover effects of prime responses on word identification (Walker, 1986), the

tasks shared the feature that no overt response to the prime was required. The first task required subjects to search for an asterisk adjacent to the prime, the second to read the prime silently, and the third to generate silently an associate of the prime. The first two tasks were found by Smith et al. to produce less priming than a semantic orienting task in lexical decision, with the asterisk task (hereafter termed "Star Search") producing no significant priming effect. Associate-generation was chosen as a task that would require semantic or elaborative processing of the prime. In a previous experiment Westbrook (1987) found that when subjects generated an associate to memory-list words their recall of the words was better than when they read words silently. In addition, they tended to produce the list word more frequently than expected from association norms when asked to free associate to a stimulus that was an associate of the word. Thus it appears that the generation task is comparable to other semantic tasks in increasing the retrievability of words (cf. Craik & Tulving, 1975).

The Star Search task was expected to induce a low level of perceptual (and consequently semantic) processing. The Read task was expected to produce a high level of perceptual processing (Jacoby, 1983) and a low level of semantic processing, whereas the Generate task was expected to produce high levels of both semantic and perceptual processing. We assessed the extent to which each task involved perceptual processing by testing the prime words for repetition effects. In addition, for the purpose of assessing the extent of semantic processing of prime words, a recall test was administered after the priming and repetition phases of the experiment. To assist recall we

provided a cue which was an associate of the prime. This cue had not been seen earlier in the experimental session (cf. Nelson & McEvoy, 1979; Humphreys, Bain, & Pike, 1989). The sensitivity of this test to "depth-of-processing" manipulations was confirmed in the above-mentioned experiment by Westbrook (1987).

EXPERIMENT 1

Method

Subjects. Seventy-two first year Psychology undergraduates of both sexes served as subjects for course credit. They were randomly allocated to three groups of 24 subjects each: Groups Generate, Read and Star Search.

Materials. Stimulus words were chosen on the basis of pilot work by the second author. All were between 4 and 7 letters long. Sixty associate pairs from the Thomson, Meredith and Browning Australian word association norms (1976) were used for priming trials. Prime and target words were approximately matched on mean length and frequency (mean frequency of occurrence for primes and targets was 84 and 100 respectively, Kucera & Francis, 1967). The mean association strength for the pairs (proportion of the norm sample giving the target as the first associate of the prime) was 28%.

An additional 40 single words (mean frequency 91, Kucera & Francis, 1967) were selected from the Thomson et al. norms for use on priming and repetition trials, as described shortly. A further set of 100 words (frequency range 1 to 472) was used for setting the stimulus duration for the word identification task, and a final set of 24 unrelated words

was randomly paired for each subject to produce 12 practice pairs for the priming phase.

The priming trials consisted of 20 related trials, 20 unrelated trials and 20 "dissimilar" trials. For each subject the set of 60 associate pairs was randomly divided into 3 equal subsets to provide 20 pairs for each of the 3 trial types. For related and unrelated trials the primes and target pairs were intact and randomly repaired respectively. For dissimilar trials, the primes were randomly paired with 20 targets taken at random for each subject from the set of additional 40 words mentioned above. Trials were presented in a random sequence with the constraint that no more than 3 related trials occurred in succession and no more than 6 consecutive trials occurred without a related trial.

For the 60 prime repetition trials, there were 40 old primes, 20 that had been seen as related and 20 that had been seen as unrelated primes. The 20 new words for each subject were those from the additional 40 word set that had not been used for dissimilar prime trials.

For cued recall, the cues were the 20 associates of dissimilar primes that had been replaced as targets by unrelated words from the additonal word pool. Thus for the dissimilar pair TIME-CRISIS, a subject was given CLOCK as a cue to recall TIME.

Procedure. Subjects were seated in front of an Amiga 1000 microcomputer with Amiga NSTC monitor. They were informed that there were several parts to the experiment. They read an instruction sheet prior to each phase of the experiment, supplemented by explanation where necessary.

Words were presented on a blue background in upper case white letters subtending a visual angle of approximately .50. Each word to be identified by the subject was followed by a mask composed of 8 randomly selected upper case consonants.

In the preliminary duration determination phase, subjects saw words in blocks of 10, with an interval of 4 sec between trials. The mask was presented for 100 ms timed from word offset. The subject was informed about the random letter mask and asked to name the briefly presented word or respond NO if unable to do so. For the first block of 10 trials, the word exposure was set at 100 ms. In subsequent blocks the duration was reduced by 20 ms (to a limit of 60 ms) after each block where the subject scored 70% correct or better, was increased by 10 ms where performance was at or below 30% correct for two consecutive blocks, or otherwise remained unaltered. When the stimulus duration reached 60 ms, decreases in duration were made in steps of 10 ms.[1] The duration set for block 11 was used for the words to be identified in the priming and repetition phases.

In the priming phase which followed immediately after the duration determination phase, subjects identified target words and responded to the prime words according to condition. Subjects in Group Generate were to think silently of a word closely associated with the prime. Subjects in Group Read were to read the prime silently, while subjects in Group Star Search were to decide whether an asterisk presented adjacent to the prime was presented to the left or the right of the word. No overt response was required.

Primes were presented for 1 sec, with a 1 sec pause following. The target was presented at the duration previously determined for the subject, and a mask was presented for 100 ms after the target, as described previously. There was a pause of 4 sec between mask offset and the next trial. Errors in target identification were manually recorded by the experimenter.

The repetition phase followed. Subjects were instructed that the task was identical to the first task (duration determination). There were 60 word identification trials at the temporal parameters set at the end of Phase 1. Errors were manually recorded.

The cued recall was administered last. Subjects were given 5 minutes to complete the test, which required them to write next to each of 20 cue words a word that was presented for 1 sec in the second part of the experiment. They were informed that the cue words provided might "remind" them of the to-be-remembered words.

Results

The mean 50% identification exposure durations for the Generate, Read and Star Search groups were in the vicinity of 40 ms[1].

The mean proportion of correct target identifications by group and condition for the priming phase are shown in Table 1. Analyses over subjects were performed to test differences in priming, repetition and cued recall for the 3 groups. Item analyses were not performed because each subject had a different sample of the 60 paired associates for each of the trial types and therefore item differences were confounded with subject differences.

Insert Table 1 about here

For the priming phase, the data for the dissimilar condition were excluded from analysis because the target items for these trials came from an item pool prepared separately from the set used for related and unrelated trials. Table 1 shows that the results for dissimilar trials are similar to those for unrelated trials. A trial type by group analysis of variance (ANOVA) on accuracy scores for related and unrelated trials revealed no main effect for group ($F < 1$), a significant priming facilitation for targets following related versus unrelated primes ($F(2,69) = 215$, $p < .001$) and a significant group by trial type interaction ($F(2,69) = 6.3$, $p < .005$). A Tukey's Honestly Significant Difference (HSD) test of priming effects showed that groups Read and Generate had greater priming effects than Group Star Search ($p < .05$), but that Groups Generate and Read did not differ on the magnitude of priming. On related trials both groups Generate and Read were more accurate than Group Star Search (Tukey's HSD, $p < .05$), whereas for unrelated trials the only significant difference was the inferior performance of Group Generate compared with Group Star Search (Tukey's HSD, $p < .05$).

The accuracy data for the prime repetition test are shown in Table 2. ANOVA for groups by word type (old vs. new) revealed no main effect for groups ($F(2,69) = 1.89$, $p > .05$), a significant difference between old and new words and a significant groups by word type interaction ($F(1,69) = 164.4$, $p < .001$ and $F(2,69) = 4.63$, $p < .05$, respectively).

Tukey's HSD indicates that both groups Generate and Read showed greater old-new differences than Group Star Search ($p < .05$), with Groups Generate and Read not differing. However, the old-new difference was reliable for Group Star Search (Tukey's HSD, $p < .01$).

Insert Table 2 about here

The percentages of primes produced in the cued recall phase for Groups Generate, Read and Star Search were 28.3%, 19.8% and 17.9% respectively. Planned comparisons revealed reliable differences between Groups Generate and Read ($F(1,69) = 4.7$, $p < .05$) and between Groups Generate and Star Search ($F(1,69) = 6.9$, $p < .05$). Groups Read and Star Search did not differ ($F < 1$).

Discussion

Priming effects on identification were evident for all prime-task groups, with Groups Generate and Read showing stronger priming than Group Star Search. In addition, all groups showed a repetition benefit in the Phase 2 word identification test of old primes and new words, with Groups Generate and Read again showing a greater effect than Group Star Search. On the final cued-recall test for primes, Group Generate was superior to both Groups Read and Star Search.

The cued recall results indicate that Generate subjects were performing the associate-generation task as instructed, and that there was a difference in the amount of semantic processing between Groups Generate and Read. This difference in semantic processing, however, did not produce a difference in priming between these groups. In

correspondence with their priming results, Groups Generate and Read showed comparable prime repetition effects, suggesting that they engaged in a similar amount of perceptual processing of the primes. The poorer repetition benefit for Group Star Search relative to the other groups suggests less perceptual processing of primes in these subjects. Consequently the present results provide support for Bentin and Katz' (1984) argument that smaller priming effects with superficial prime-processing tasks are attributable to inadequate perceptual processing of primes (failure to process primes as "whole words") rather than a lack of semantic processing. Nevertheless, the demonstration of a repetition effect for primes in Group Star Search indicates some whole word processing of primes, although we cannot rule out the possibility that some primes received full processing and others received attenuated processing.

It is somewhat surprising that the generation of an associate to the prime by Group Generate did not produce more priming than that observed in subjects merely reading the prime. This result is inconsistent with previous lexical decision research showing greater priming with semantic prime processing instructions than with silent reading of the prime (e.g., Smith et al., 1983). One explanation for the failure to replicate previous depth-of-prime-processing research is that previous studies, which had no separate assessment of perceptual processing of primes, produced more superficial prime processing in the silent read conditions than did our study. For example, subjects may attend more to primes in a perceptual identification task than in a lexical decision task because subjects are more aware of the effect of

the primes on their accuracy of responding than on their latency of responding.

A second possibility is that Group Generate subjects were more likely than Group Read to adopt a strategy of predicting the target from the prime, but their greater use of a prediction strategy was not reflected in better performance than Group Read on related prime trials. That is, the prediction strategy, which produces facilitation when the prediction is correct and inhibition when it is incorrect (Neely, 1977), may have produced no net benefit on the related trials relative to the level observed in Read subjects. The trend towards inferior performance of Group Generate relative to Group Read on unrelated prime trials supports this possibility. Unfortunately, it is also arguable that the unrelated prime results for Group Generate arise not from an inhibitory process but from an overall inferiority at the perceptual identification task in this group of subjects. It is noteworthy that during the repetition test, Group Generate performed more poorly on new words than the remaining two groups. Although this result may reflect differential use of retrieval or other strategies in Generate subjects, it most plausibly suggests lower ability in word identification in this group.

Experiment 2 was designed to investigate further the possible role of a prediction stategy in priming when subjects generate an associate to the prime.

EXPERIMENT 2

Associative strength of prime target pairs, and therefore target predictability, was varied over two levels (high and low) within subjects. Three between-subjects conditions were employed. The first two

groups corresponded to the Read and Generate groups of Experiment 1. A third, "guessing", group was introduced to view the priming stimuli at a longer prime-target interval and predict in writing the target from the prime. The responses provided by Group Guess were used to estimate the probability of predicting targets from primes in the weak and strong associate conditions. Thus, by contrasting two levels of association and providing an independent estimate of the success of target prediction from primes, the design allows a more direct assessment of the extent to which priming effects in Groups Read and Generate are attributable to the use of a prediction strategy.

The Read and Generate Groups were subsequently tested on cued recall for primes, as in Experiment 1. The prime repetition test, which did not distinguish the Read and Generate groups in Experiment 1, was omitted.

Method

Subjects. 72 male and female First Year Psychology students participated for course credit. They were randomly divided into the 3 groups Generate, Read and Guess (N = 24 each).

Materials. All words were 4-6 letters long. Sixty target words (mean frequency 100, Kucera & Francis) were selected with a weak and strong associative stimulus as a prime for each (mean frequency: 83 and 68 respectively), with primes and targets approximately matched on length. The strong associative primes were taken from the Thomson et al. norms and the prime-target pairs had a mean associative strength of 28 %. The weak primes were taken from Thomson et al., Miller (1970), Palermo and Jenkins (1964) or were made up. The associative strengths

for weak pairs taken from norms ranged from 1 to 8%, 5 to 10%, and 2 to 17% respectively.

An additional set of 40 words matched to the targets on mean length and frequency provided targets for a dissimilar prime condition which served as an unrelated prime control. A further set of 48 unrelated words was divided into 24 primes and 24 targets which were randomly paired for each subject to make up an initial block of practice trials. Finally, 100 single words were used for stimulus duration determination as described in Experiment 1.

Each subject in each of the 3 groups saw a randomly selected set of 20 targets with weak primes and a set of 20 different targets with strong primes. The strong primes for the remaining 20 targets were paired with 20 randomly selected unrelated targets from the additional pool of 40 words. Trials were presented in a random sequence with the constraint that no more than 3 "strong" trials occurred in succession and no more than 6 consecutive trials occurred without a strong trial.

For the cued recall test, the normatively associated unpresented targets for the dissimilar-condition primes were used as cues for the recall of the primes.

Procedure. For Groups Read and Generate the duration determination, priming and cued recall phases were conducted as for Experiment 1. Group Guess saw each prime for 1 sec and its target, unmasked, for .5 sec on an Amiga display similar to that used for the Read and Generate Groups. A 5 sec delay was interposed between prime offset and target onset. Subjects were instructed to "try to guess the next word" occurring after the prime, and to write their guess for each

word on an answer sheet with numbered trials. They were informed that the words were sometimes related and sometimes unrelated. At the end of each trial the trial number was shown on the screen. The inter-trial interval was 4 seconds.

Results

Priming phase data for Groups Read and Generate are shown in Table 3. Because the dissimilar and unrelated prime-target pairs produced comparable performance in Experiment 1, the data for the dissimilar trials were used to provide the unrelated condition scores in the statistical analyses. A groups by trial-type ANOVA shows a significant difference for the three trial types ($F(2,92) = 117.3$, $p < .001$), no reliable group effect ($F < 1$) and a non-significant groups by trials interaction ($F(2,92) = 2.6$, $p = .08$). Tukey's HSD test shows that for each group separately, all pair-wise comparisons between the three trial types are significant ($p < .05$). Table 3 shows that Groups Read and Generate performed similarly on related trials but that Group Generate tended to be less accurate than Group Read on unrelated trials. Some evidence for an inhibitory effect on dissimilar targets in Group Generate relative to Group Read was provided by a significant groups by trial-type interaction when responses for weak and strong related trials were pooled ($F(1,92) = 4.1$, $p < .05$).

On cued recall for dissimilar primes Group Generate performed better than Group Read (a mean proportion of .40 vs. .30 primes recalled, $F(1,46) = 4.5$, $p < .05$).

The responses for Group Guess were scored according to the prime-target relation, with the mean proportion correct for strong associates,

weak associates and dissimilar pairs being .35, .03 and 0 respectively ($F(2,46) = 118.6$, $p < .001$). The results for strong associates correspond quite closely with the mean associative strength of the pairs reported in the word association norms from which words were selected (.28).

Discussion

Subjects who read the prime silently showed associative priming as strong as that shown by subjects who silently generated an associate of the prime. In addition, both groups showed stronger facilitation of target recogntion when the prime was a strong associate than when it was a weak associate. This result demonstrates a strength of association effect in perceptual identification that has been elusive in lexical decision experiments (see de Groot et al., 1982). Consistent with Experiment 1, the two groups differed in cued recall, indicating that Group Generate engaged in more elaborative or semantic processing of the prime than did Group Read.

The weaker performance in the dissimilar prime condition for Group Generate relative to Group Read is consistent with an accuracy cost incurred through a reliance on a prediction or other strategy in this group. Some evidence supports this conclusion. First, a similar trend was observed for this group in Experiment 1. Second, the proportion correct for dissimilar targets in these subjects (.36) clearly falls short of the .50 accuracy achieved during Phase 1 (duration determination) ($t(1,23) = 3.1$, $p < .01$). However, the overall poor performance of Generate subjects in Experiment 1, and their unpredicted decline in that experiment from .50 in Phase 1 to .34 for new words in

the Repetition phase, throws doubt on this evidence. Consequently, no firm conclusion can be drawn about inhibitory effects on unrelated trials in the absence of an appropriate neutral priming condition.

Although we cannot confidently draw inferences about inhibition on unrelated trials, the data provided by Group Guess give a clear indication of the extent to which Read and Generate subjects are using a simple predict-and-match strategy for target identification on priming trials. Those data indicate that although subjects were moderately successful at guessing the strong associate of a prime, they were unable to guess the weak associate. Thus a simple strategy where only one prediction of the target is made should produce no priming benefit on weak associate trials. However, a substantial effect was found.

More formally, if we assume that Group Generate subjects are relying on a simple predict-and-match strategy, we can estimate the predictability of weakly associated targets that is large enough to produce the magnitude of priming observed for these targets. We represent the probability of identification of the target under a simple predict and match strategy in terms of the probability of correctly generating the target (P(Gen)), and the probabilty of identifying the target when it has or has not been correctly generated (P(Id|Gen) or P(Id|~Gen) respectively):

$$P(Id) = P(Gen).P(Id|Gen) + P(\sim Gen).P(Id|\sim Gen)$$

(i) P(Id) is estimated from the identification probability for related targets with weak associates (.69); P(Id|Gen) is set at its maximum of 1; P(~Gen) = 1 - P(Gen); and P(Id|~Gen) is estimated from accuracy on dissimilar prime trials (.36).

We substituted the above values into equation (i) to solve for the predictability (P(Gen)) of weakly associated targets, and obtained a value of .52. This result is more than 17 times larger than the prediction accuracy achieved by Group Guess for weakly associated targets (.03).

A second source of evidence suggesting that subjects generating an associate of the prime were not employing a simple predict-and-match strategy comes from a comparison of intrusion errors for the two prime-task groups. The groups had similar means for the number of words erroneously given as the target during priming (4.88 & 5.71 for Generate & Read respectively). All intrusions for the two groups were classified as associatively or semantically related to the prime, or unrelated, by the first author. Intrusions were judged to be related if they were common associates of the prime, or obviously shared a synonymy, category or other semantic relationship with the prime (e.g., bread-loaf, sunburn-red, heaven-God, scratch-back, steam-kettle, bloom-bud). The small number of pairs whose semantic relatedness was in doubt were classified as unrelated (e.g., warmth-love, bread-dinner). The proportion of related intrusions was calculated for each subject. The important result of this analysis was there was no difference between the groups in the mean proportion of intrusions that were semantically related to the prime (Generate: 48%, Read: 53%). Because only a very small proportion of related intrusions resembled the target visually or phonologically, it appears that many of the related intrusions were guesses made when subjects had little perceptual information about the target.

General Discussion

The results from the first experiment support Bentin and Katz' (1984) conjecture about reduced priming levels being caused by a lack of "whole word" or perceptual processing. Our experiment differed from Bentin and Katz' experiment in that we measured the extent to which prime processing tasks induced perceptual processing instead of trying to infer it on intuitive grounds. We found that Star Search subjects showed a reduced repetition effect (our measure of perceptual processing) relative to Generate and Read subjects. Although the repetition effect was reduced it was still significant for the Star Search subjects. Consequently it is unclear whether there was reduced perceptual processing for all words or whether subjects processed some primes fully and others inadequately. This question could be studied in a naming or lexical decision task by showing that there was a bimodal distribution of latencies in the related condition of the Star Search task. At this point we cannot be sure that the reduction in priming reported by Henik et al (1983), Parkin (1979) and Smith et al (1983) was due to inadequate perceptual processing. Certainly it is a plausible hypothesis that reduced perceptual processing of primes underlies differences in the magnitude of priming that have been attributed to differences in subjects'strategies. An additional example, mentioned previously, is the variation in priming that has been reported in the lexical decision task when the proportion of related prime trials is varied. This effect may result from poorer processing of primes when the proportion of related trials is low. The above hypothesis could be investigated with the aid of a prime repetition test to assess

perceptual processing of the prime. Our results suggest that this test is a valuable diagnostic tool for studying hypothesised prime processing effects.

There was no difference in priming and no difference in the repetition effect between Groups Generate and Read. There was, however, a difference in cued recall indicating that we had been successful in producing differences in the amount of semantic or elaborative processing of the primes. There was also a trend towards lower performance in the unrelated condition for the Generate subjects relative to the Read subjects. This trend suggested that the Generate subjects may have been more likely to employ a prediction strategy which was producing benefits when the prediction was correct and costs when the prediction was wrong.

To test this hypothesis in Experiment 2 we used three levels of associative strength (strong, weak and unrelated) and employed a Guessing group in addition to the Generate and Read Groups. The results were unequivocal. The accuracy of identification of targets with weak associates as primes was much higher than the accuracy with which these targets were produced by the Guessing subjects, and hence a simple predictive model of priming is not supported. That is, the subjects could not have been using the prime to generate one or a few possibilities prior to the presentation of the target. These results also rule out a simple guessing model in which subjects use the prime to generate a guess whenever the perceptual information available is inadequate for target identification.

It is less straightforward for us to reject a more sophisticated guessing model in which the subject uses the prime to continuously generate words until one matches the partial perceptual information extracted from the target, or uses partial perceptual information about the target to continuously generate words until one is related to the prime. Nevertheless both of these alternatives seem unlikely. In relation to the first alternative, we find from our previous discussion of a simple prediction strategy that the target would have to be generated from the prime 52% of the time to account for the observed priming effect with weak associates (.69 = .36 + (1 - .36) P(Gen)). Without continuous association data we cannot ascertain whether subjects could achieve such prediction accuracy when they continuously generate target candidates. However, 52% success is unlikely given that the Guessing subjects only produced these targets 3% of the time. The first alternative is also weakened by the observation that virtually all the related intrusions and approximately 30% of the unrelated intrusions by Groups Generate and Read in the two experiments were not visually similar to the target. The other alternative, namely that the subject uses partial perceptual information to generate alternatives which are then compared to the prime, fares no better. In Experiment 1 Read and Generate subjects did produce more intrusions that were semantically related to the prime than did Star Search subjects (36%, 33% and 13% respectively). However the absolute number of these intrusions was quite low, being 3.8, 3.9 and 1.5 respectively, for the 60 trials.

The adequacy of sophisticated guessing accounts can also be questioned on the basis of a memory research finding discussed by

Humphreys et al. (1989). The result was reported in an investigation of the cue plus stem implicit memory test (see Graf & Schacter, 1985). In one of the conditions employed by Graf and Schacter subjects studied pairs of unrelated words. They were then given a cue word and the first three letters of the target word and asked to produce the first word that came to mind that completed the stem. The presence of the study cue at the time of test enhanced performance relative to the presence of another unrelated word. In this task subjects could not use a strategy of generating to the cue term because the probability of generating the target term was essentially zero. Furthermore they could not use a strategy of generating to the stem because the words they generated would be unrelated to the cue. It is true that Graf and Schacter's subjects could have checked the episodic appropriateness of the words that they generated by trying to recognize whether the word they generated had been paired with the cue word during study. However, this would not have been possible for those amnesic subjects who were able to perform this task. Humphreys et al.'s conclusion was that the cue and the stem were not operating independently to affect retrieval. Instead they were combining to increase the probability that the target word was the first word produced.

Our results strongly suggest that a similar explanation is required for priming in the perceptual identification task, because the magnitude of priming observed cannot readily be explained by a strategy of testing against target information candidates already retrieved from memory. Specifically, the prime and the degraded physical representation of the target must combine to affect retrieval so that the target lexical entry

is more likely to be the first lexical entry accessed. Just how this is accomplished is not indicated by our results. The traditionally invoked spread-of-activation hypothesis (Collins & Loftus, 1975) is one way to combine information from both the prime and the physical cue to affect lexical access. Although this account was rejected as an explanation of certain depth-of -prime- processing effects (e.g., the difference between silent reading and semantic processing of the prime reported by Smith et al., 1983), it can accommodate the present finding that the magnitude of priming appears to depend only upon the adequacy of the perceptual processing of the primes.

An alternative approach is the distributed associative theory proposed by Humphreys et al. (1989), which locates priming effects at target processing rather than prime recognition (see also Norris, 1986, & Ratcliff & McKoon, 1988). According to Humphreys et al. the prime activates a pre-existing association between prime and target which combines in the retrieval process with the activated association between the target's input memory code and its central memory code.

The two theories are similar in terms of their account of short term priming effects. The associative account has the potential to provide a superior explanation of long-term priming effects, such as the repetition effect observed for primes in Experiment 1. The reason for this is that the associative account relies on the strengthening of associations between input and central memory codes, rather than the problematical notion of long-lasting residual activation at a lexical node.

References

Becker, C. A. (1979). Semantic contexts and word frequency effects in word recognition. Journal of Experimental Psychology: Human Perception an Performance, 5, 252-259.

Bentin, S., & Katz, L. (1984). Semantic awareness in a non-lexical task. Bulletin of the Psychonomic Society, 22, 381-384.

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. Memory and Cognition, 8, 493-512.

Burke, D. M., White, H., & Diaz, D. L. (1987). Semantic priming in young and older adults: Evidence for age constancy in automatic and attentional processes. Journal of Experimental Psychology: Human Perception and Performance, 13, 79-88.

Chumbley, J. I., & Balota, D. A. (1984). A word's meaning affects the decision in lexical decision. Memory and Cognition, 12, 590-606.

Collins, A. M. & Loftus, E. F. (1975). A spreading activation theory of semantic processing. Psychological Review, 82, 407-428.

de Groot, A. M. B. (1984). Primed lexical decision: Combined effects of the proprtion of related prime-target pairs and the stimulus-onset asynchrony of prime and target. Quarterly Journal of Experimental Psychology, 36A, 253-280.

de Groot, A. M. B. (1985). Word-context effects in word naming and lexical decision. Quarterly Journal of Experimental Psychology, 37A, 281-297.

den Heyer, K. (1985). On the nature of the proportion effect in semantic priming. Acta Psychologica, 60, 25-38.

den Heyer, K., Briand, K., & Dannenbring, G. L. (1983). Strategic factors in a lexical-decision task: Evidence for automatic and attention-driven processes. Memory and Cognition, 11, 374-381.

den Heyer, K., Briand, K., & Smith, L. (1985). Automatic and strategic effects in semantic priming: An examination of Becker's verification model. Memory and Cognition, 13, 228-232.

Evett, L. J., & Humphreys, G. W. (1981). The use of abstract graphemic information in lexical access. Quarterly Journal of Experimental Psychology, 33, 325-350.

Feustel, T. C., Shiffrin, R. M., & Salasoo, A. (1983). Episodic and lexical contributions to the repetition effect in word identification. Journal of Experimental Psychology: General, 112, 309-346.

Fischler, I. (1977). Associative facilitation without expectancy in a lexical decision task. Journal of Experimental Psychology: Human Perception and Performance, 3, 18-26.

Fischler, I. & Goodman, G. O. (1978). Latency of associative activation in memory. Journal of Experimental Psychology: Human Perception and Performance, 4, 455-470.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. Journal of Experimental Psychology: Learning, Memory and Cognition, 10, 680-698.

Graf, P., & Schacter, D., L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. Journal of Experimental Psychology: Learning, Memory and Cognition, 11, 501-518.

Henik, A., Friedrick, F. J., & Kellogg, W. A. (1983). The dependence of semantic relatedness effects upon prime processing. Memory and Cognition, 11, 366-373.

Humphreys, M. S., Bain, J. D., & Pike, A. R. (in press). Different ways to cue a coherent memory system: a theory for episodic, semantic and procedural tasks. Psychological Review.

Jacoby, L. L. (1983). Remembering the data: Analysing interactive processes in reading. Journal of Experimental Psychology: Learning, Memory and Cognition, 9, 21-38.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. Journal of Experimental Psychology: General, 110, 306-340.

Jacoby, L. L., & Witherspoon, D. (1982). Remembering without awareness. Canadian Journal of Psychology, 36, 300-324.

Kirsner, K., Milech, D., & Standen, P. (1983). Common and modality-specific processes in the mental lexicon. Memory and Cognition, 11, 621-630.

Koriat, A. (1981). Semantic facilitation in lexical decision as a function of prime-target association. Memory and Cognition, 9, 587-598.

Kucera, H., & Francis, W. N. (1967). Computational analysis of present-day American english. Providence, RI: Brown University Press.

Lorch, R. F. (1982). Priming and search processes in semantic memory: A test of three models of spreading activation. Journal of Verbal Learning and Verbal Behavior, 21, 468-492.

Lorch, R. F., Balota, D. A., & Stamm, E. G. (1986). Locus of inhibition effects in lexical decisions: Pre- or Postlexical Access? Memory and Cognition, 14, 95-103.

Marcel, A. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. Cognitive Psychology, 15, 197-237.

Meyer D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognising pairs of words: Evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90, 227-234.

Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. (1974). Loci of contextual effects on visual word recognition. In P. Rabbitt (Ed.), Attention and Performance V. (pp. 98-118). New York: Academic Press.

Miller, K. M. (1970). Free-association responses of English and Australian students to 100 words from the Kent-Rosanoff word association test. In Postman, L., & Keppel, G. (Eds), Norms of Word Association. New York: Academic Press.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited capacity attention. Journal of Experimental Psychology: General, 106, 226-254.

Nelson, D. L., & McEvoy, C. L. (1979). Encoding context and set size. Journal of Experimental Psychology: Human Learning and Memory, 5, 292-314.

Norris, D. (1986). Word recognition: Context effects without priming. Cognition, 22, 93-136.

Palermo, D. S., & Jenkins, J. J. (1964). Word association norms: Grade school through college. Minneapolis: University of Minnesota Press.

Parkin, A. J. (1979). Specifying levels of processing. Quarterly Journal of Experimental Psychology, 31, 175-195.

Ratcliff, R., & McKoon, G. (1988). A retrieval theory of priming in memory. Psychological Review, 95, 385-408.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology: Human Perception and Performance, 3, 1-17.

Seidenberg, M. S., Waters, G. S., Sanders, M., & Langer, P. (1984). Pre- and postlexical loci of contextual effects on word recognition. Memory and Cognition, 12, 315-328.

Smith, M. C., Theodor, L., & Franklin, P. E. (1983). The relationship between contextual facilitation and depth of processing. Journal of Experimental Psychology: Learning, Memory and Cognition, 9, 697-712.

Stanovich, K. E., & West, R. F. (1983). On priming by sentence context. Journal of Experimental Psychology: General, 112, 1-36.

Thomson, D. M., Meredith, S. G. & Browning (1976). Monash free association norms. Monash University.

Tweedy, J. R., & Lapinski, R. H. (1981). Facilitating word recognition: Evidence for strategic and automatic factors. Quarterly Journal of Experimental Psychology, 33A, 51-59.

Tweedy, J. R., Lapinski, R. H., & Schvaneveldt, R. W. (1977). Semantic-context effects in word recognition: Influence of varying the proprtion of items presented in appropriate context. Memory and Cognition, 5, 84-89.

Walker, M. (1986). The role of strategic processes in associative priming. Unpublished honours thesis, University of Queensland.

Warren, R. E. (1972). Stimulus encoding and memory. Journal of Experimental Psychology, 94, 90-100.

West, R. F., & Stanovich, K. E. (1982). Source of inhibition in experiments on the effect of sentence context on word recognition. Journal of Experimental Psychology: Learning, Memory and Cognition, 8, 385-399.

Westbrook, K. (1987). A levels of processing effect in the priming of free associations. Unpublished honours thesis, University of Queensland.

Author Notes

The research reported here was supported by Grant 634 from the Australian Research Grants Scheme. Requests for reprints should be sent to J. Burt, Department of Psychology, University of Queensland, Qld., 4067, Australia.

Footnotes

[1]It was discovered after completion of the experiments that the monitor used for stimulus presentation had a 20 ms scan rate that precluded adjustments of less than 20 ms in presentation duration. Therefore the precise target presentation durations for each subject are unknown.

Table 1

Experiment 1: Mean Proportion of Correct Target Identifications During the Priming Phase. Standard deviations are shown in in parentheses.

	Prime-target relation		
Group	Related	Unrelated	Dissimilar
Generate	.79 (.13)	.31 (.15)	.33 (.16)
Read	.78 (.12)	.39 (.20)	.37 (.21)
Star Search	.70 (.14)	.44 (.20)	.43 (.21)

Table 2

Experiment 1: Mean Proportions of Correct Identifications in the Repetition Test for Old Primes (Pooled Over Related and Unrelated) and new words. Standard deviations are shown in parentheses.

	Word type	
Group	Old	New
Generate	.60 (.13)	.34 (.14)
Read	.66 (.14)	.43 (.18)
Star Search	.57 (.15)	.42 (.17)

Table 3

Experiment 2: Mean Proportions of Correct Identifications in the Priming Phase For Each of the 3 Trial Types. Standard deviations are shown in parentheses.

	Prime-target relation		
Group	Strong association	Weak association	Dissimilar
Read	.79 (.15)	.67 (.20)	.45 (.21)
Generate	.81 (.16)	.69 (.14)	.36 (.22)